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FURTHER DATA ON THE GROWTH OF DOUGLAS-FIR
TREES OF KNOWN SEED SOURCE¹

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In 1912 seed was collected from 125 individual Douglas-fir trees from 13 localities in western Washington and western Oregon which typified various climates and soils; the mother trees were selected as representing a variety of contrasting conditions--young trees, middle-aged trees, and old trees, open-grown and forest-grown trees, sound and "conky" trees. In most cases seed collections were made from several parent trees of a like kind in each locality.

Seedlings were grown in the Wind River Nursery from each lot of seed, the progeny of each parent being kept separate. When two years old an equal number of little trees of each lot was planted in each of six areas representing a variety of climatic conditions. The number of trees of each parentage ranged from 10 to 100, most lots having 20 trees. A uniform diagram of out planting was followed in all cases.

In 1916 stock grown from the remaining seed was out planted in companion plantations as a replica of the 1915 plantations. The number of trees planted in 1916 was about a third as large, there being 10 trees or less in each lot.

The trees were all individually numbered and tagged. In 1915 and 1916 they were checked twice for survival and growth. Thereafter they were examined for survival and injuries and measured for height growth in 1917, 1918, 1919, 1921, 1923, 1925, 1928, and 1931.

An analysis of the findings up to this last date was made and published in 1936 as U.S.D.A. Tech. Bul. 537, "Growth of Douglas Fir Trees of Known Seed Source" by the present authors. This bulletin describes in detail, which need not be repeated here, the seed sources, the planting areas, and the methods of establishing and caring for these plantations.

The present report should be considered as a supplement to the published bulletin; it records the history of these plantations from 1931 to 1941. It gives data on the survival and height of these plantations as of the examination in the fall of 1941 and analyzes the relationship between height

¹/ Assistance in the compilation of the data contained in this report was furnished by the personnel of Work Projects Administration official project 3228.

growth and parentage and also the relationship of planting site to growth irrespective of parentage.

Brief Description of Plantation Areas

The original plantation areas are six in number, named for the forests upon which they are located, as follows:

Wind River Experimental Forest (within the Columbia National Forest) - seven miles (air line) north of the Columbia River at Carson, Washington at an elevation of 1,100 feet.

Mt. Hood A - on the national forest of that name on the Still Creek drainage eight miles from Zigzag Ranger Station at an elevation of 2,800 feet.

Mt. Hood C - midway between Mt. Hood A and B. Both the 1915 and 1916 plantations were wiped out by fire in 1917.

Mt. Hood B - near the top of a ridge on the Still Creek drainage, two miles from Mt. Hood A and at an altitude of 4,600 feet.

Siuslaw - on the national forest of that name on the Coast Range near the summit of Little Mt. Hebo at an elevation of 2,100 feet, 10 miles from the ocean.

Snoqualmie - on the national forest of that name in the South Fork of the Stillaguamish River drainage area near Silverton, Washington, at an elevation of 2,000 feet.

The elevations of the plantations do not indicate the comparative differences in climate, because the Siuslaw area is within the temperate influence of the ocean while the other areas are in the Cascade Mountains. There is also a pronounced difference in latitude between the Snoqualmie area and the others.

Both the 1915 and 1916 plantations on the Wind River, Mt. Hood A, and Mt. Hood B areas are extant (though an end of the latter was destroyed by fire in 1917), but the 1915 plantation on the Snoqualmie and the 1916 plantation on the Siuslaw area were abandoned in 1917 largely because of rodent depredations. Thus, there were but eight plantation units under observation in the decade 1931 to 1941.

Dates and Character of Examinations

Until and through 1931 all plantations were measured for total height, using a pole. By this time some of the trees were becoming too tall for convenient measurement and it became necessary to convert to diameter measurement. In 1928 and 1931 the Siuslaw trees and in 1931 the trees on the

other plantations which were big enough to have a measurable diameter at breast height were measured or, in the case of the very small trees, estimated. In 1936 the undamaged trees of the Mt. Hood B plantation were measured for height, but not for diameters.

In 1941 the trees on all plantations were measured for diameter alone. On the Siuslaw and Snoqualmie areas diameter tapes were used and on the other areas chiefly small calipers, which are thought to give the same results for these small trees and to be more reliable in the hands of inexperienced CCC measurers.

A hundred or so representative heights were taken in 1941 on the Wind River area, and a few on Mt. Hood A, to give an indication of the prevailing heights on each area regardless of heredity.

No cultural work was done on any of these plantations in this decade. Tags were reset in many cases, the nails pulled to provide for growth and in some lost tags were replaced. A cedar corner post on the Siuslaw plantation, lettered with black glossy carriage paint in 1915 by C. J. Kraebel, which was clearly legible and in a good state of preservation, was removed as an exhibit and replaced with a scribed post. Some of the signboards were renewed. A trail was built through the Wind River plantation without cutting any trees for the benefit of visitors.

In addition to noting at each examination whether a tree was dead or alive and its diameter at breast height, observation was made of injuries, of which there were many in some plantations. Symbols were used to denote such things as broken top, crushed, wind thrown, snow damage, and suppressed. These injuries have not been compiled since it was thought they had no significant relation to the heredity of the planted trees, at least none that could be detected from the relatively few instances there would be in each lot.

The Seed Source By Locality and Character of Parent Trees

The seed was collected in 13 different localities; though distributed from northwestern Washington to central western Oregon they by no means represent all the varieties of soil, altitude, climate, and exposure that occur in this diversified Douglas-fir region. Unfortunately they do not comprise full series which are similar in all factors except one, such as from low to high altitudes or from north to south or from the best to the poorest soils.

The localities of collection and their altitudes are as follows, beginning at the north:

Darrington, Washington	500 feet
Fortson, Washington	500 "
Hazel, Washington	900 "
Granite Falls, Washington	400 "
Lakeview, Washington	100 "

Race Track Trail - Columbia Nat. For.	2,600 feet
Wind River Valley - Columbia Nat. For.	1,250 & 1,400 feet
Carson, Washington	400 feet
Palmer, Oregon	2,000 & 3,000 feet
Portland, Oregon	300 feet
Gates, Oregon	950 & 1,000 feet
Santiam River Watershed - Oregon	2,800 & 3,850 feet
Benton, Oregon	700 feet

The parent trees ranged in age from very young trees to those over 200 years, and came from open-grown stands and from crowded stands, some were infected with fungi and some sound. Some collection localities afforded several parent tree variations, others only one condition.

The collections were so made that various parent tree groups could be set off in pairs ostensibly similar in all respects except one, with the purpose of detecting this one variable on the progeny. These factors were: (1) altitude - high or low; (2) soil - good or poor; (3) age - young, medium, or old; (4) fungus infection - infected or not infected with red ring rot; (5) stand density - open or dense grown.

Survival and Mortality

An analysis of mortality for the period up to 1923 inclusive was made and published in U.S.D.A. Tech. Bul. 537. Realizing that there might be many unequalities in mortality due to variations in planting technique and to differences in weather during establishment, the data for first-year mortality were analyzed separately. "They showed no relation between mortality and source of seed."^{2/} Accordingly mortality percentages were computed from the number of trees alive one year after planting and the number alive in 1923. These percentages "show no significant difference in the ability of the various stocks to establish themselves and survive on any of the test-plantation areas."^{2/}

Much of the mortality following the first-year losses has been due to external influences, such as fire, rodent gnawing, snow breakage, crushing by falling snags, limbs or bark, deer browsing, which for the most part are not selective. No observable relationship between the parentage of the trees and their ability to survive is to be expected. This holds true for the smaller amount of mortality that has occurred since 1923, so no attempt will be made here to analyze mortality by parent tree origin or character.

In a paper^{3/} by the senior author the mortality of these plantations is summarized in a table which is reproduced herewith as table 1.

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- ^{2/} Munger, T. T. & Morris, W. G. Growth of Douglas-fir trees of known seed source. Tech. Bul. 537. December 1936.
- ^{3/} Munger, T. T. Vital statistics for some Douglas-fir plantations. Jour. of Forestry, Vol. 40. 1942.

TABLE 1

Mortality of 12 Douglas-fir Plantations 1 year,
10 (or 9) Seasons, and 27 (or 26) Seasons After Planting

Name of plantation	Planted in spring of	No. ¹ / _{planted}	Percent dead ² / _{after one year ³/}	Percent dead ² / _{in Fall, 1925}	Percent dead ² / _{in Fall, 1941}
Wind River	1915	3,125	11.0	28.2	35.1
Mt. Hood A	1915	3,106	4.3	7.9	10.4
Mt. Hood C	1915	3,103	3.0	--	--
Mt. Hood B	1915	3,094	5.8	36.3	57.4
Siuslaw - Hebo	1915	3,111	12.0	23.1	30.2
Snoqualmie	1915	3,103	36.7	--	--
Average of 1915 Plantations			12.1	18.9 ⁴ /	33.2 ⁴ /
Wind River	1916	1,051	7.6	23.2	35.8
Mt. Hood A	1916	1,049	5.8	16.0	18.2
Mt. Hood C	1916	1,048	11.1	--	--
Mt. Hood B	1916	1,049	9.5	29.0 ⁵ /	58.7 ⁵ /
Siuslaw - Hebo	1916	1,046	36.1	--	--
Snoqualmie	1916	1,034	3.7	19.1	32.0
Average of 1916 Plantations			12.3	21.8 ⁴ /	36.2 ⁴ /

¹/ In a few cases there is a very slight disparity between actual "number planted" and the number of trees for which the record is available for the calculation of mortality percent at the several periods.

²/ "Dead" includes trees missing and presumably dead.

³/ Based on the examination of June 1916 for the 1915 plantations and the June 1917 examination for the 1916 plantations.

⁴/ Exclusive of catastrophic losses that wrecked almost all of certain plantations and caused their abandonment.

⁵/ Not including the trees killed by a forest fire in 1917 which covered about a quarter of this plantation and killed all the trees in its path.

This table shows that with two exceptions all 12 planting jobs had a satisfactory initial survival of from 88 to 97 percent. Excluding the extraordinary and catastrophic losses on four plantations which necessitated their abandonment it shows that losses continued so that by 1941 the 1915 plantations had only 66.8 percent survival and the 1916 plantations 63.8 percent survival. From 1925 to 1941 the mortality averaged about 1 percent a year.

In addition to the trees killed by animals, the elements, and falling missiles, many trees were injured so that their growth is impaired and they become more easily overtopped and suppressed by their neighbors.

Methods of Analyzing the Variation in Diameters of 1941

It was necessary to obtain a numerical standard for judging the significance of differences in the mean diameters of different groups of progeny. The unaided judgment of the investigator is not sufficiently reliable to determine if two averages such as 4.4 inches and 4.6 inches each based on 50 trees are significantly different or whether they should be considered within the range of variation that can be frequently expected owing to lack of uniformity in experimental conditions.

Experience with analysis and interpretation of the height measurements during the preparation of U.S.D.A. Tech. Bul. 537 indicated that the computing work required to obtain the standard error of each mean diameter that the investigator might wish to compare with another mean would be greater than the results of the present analysis would justify. It was decided, therefore, to compute a few sample variances for the Wind River, Mt. Hood A, and Siuslaw plantations and use these as guides for interpreting the differences in means on the given plantation. Four of the rows that run the full length of the 1915 plantations and contain progeny from a given parent were chosen arbitrarily. These long rows each with 60 to 90 surviving trees in 1941 represent a longitudinal cross section of the oblong plantation areas and the variation within these rows should give a reasonably good measure of the variation due to site differences within the plantations. Rows representing the same parent trees were selected on the three plantations. The seed source localities were Carson, Lakeview, Gates, and Santiam. After the variance for each row was computed it was possible to determine the number of trees necessary to make significant any given difference in two samples having the same variance. Using these computed numbers from each of the four rows as a guide in the given plantation the mean diameters for the various seed source groups were compared and differences appearing significant were noted. The Mt. Hood B plantation was not included because the trees had suffered severe top killing below breast height. The 1916 plantations were not included because they did not furnish sufficient trees in many seed source groups.

Effect of Seed Source Locality on Diameter in 1941

For each of the three 1915 plantations studied critically the mean diameter representing all of the trees from a given seed source locality, such as Carson, Wind River, Portland, etc., was compared with the mean representing

each of the other 12 localities. All differences appearing significant were listed for further comparison and study. This further study showed that for most of the differences found on a given plantation similar significant differences between the same seed sources were not found on the two other plantations. Thus, in most cases progeny from seed sources that apparently differed significantly on one plantation showed no significant difference on another plantation.

The differences in diameter of progeny from the several seed sources on three plantations, together with their rank according to height in 1931 and according to diameter in 1941, are given in table 2. A summary of the comparisons of diameters in 1941 follows: The Gates and Palmer stocks are in the significantly larger size classes on the three 1915 plantations. The Wind River stock is significantly smaller than several other stocks on each plantation and is not significantly superior to any. Its average diameter is near the minimum on each plantation. The Carson stock is significantly smaller than several others on each plantation but is also significantly superior to several on the Siuslaw plantation.

In the analysis of 1931 heights for U.S.D.A. Tech. Bul. 537 the Granite Falls stock was superior to nearly all other stocks on each of the three 1915 plantations discussed here. The present analysis of diameters shows it, as before, on the Wind River plantation ranking as number 1. Five other stocks in 1941 are slightly, though not significantly larger, on the Siuslaw compared to two before. Three are significantly larger on the Mt. Hood A planting in 1941 whereas two were only slightly larger in 1931.

The Darrington stock is another that appeared better than average in 1931. This stock in 1941 has nearly the same diameter relationship compared to other stocks as the height relationship held in 1931 on the Wind River and Mt. Hood A plantations. On the Siuslaw plantation, however, three stocks in 1941 exceed it slightly in diameter whereas none exceeded it in height in 1931.

Effect of Tree Classes on Diameter

It was intended originally that all progeny from a given class of parent, as for example old, young, open grown, densely grown, fungus infected, non-infected, low altitude, and high altitude could be grouped for comparison with those from another class regardless of seed source locality. Since the progeny from different localities appear, however, to differ significantly in diameter a group of progeny from young parents must contain trees from the same seed source localities as a group from old parents with which it is to be compared. Otherwise the two groups would not be balanced in all factors except age. Seed collected in four of the 13 localities represented only one class of parents and so the progeny from these cannot be used in any of the comparisons of parent tree classes. In most of the classes of parent tree, seed was not collected from a sufficient number of trees and localities to make a conclusive test of contrasting classes, but comparisons of the diameters in 1941 have been made for the various contrasting classes.

TABLE 2

Average Diameters in 1941 of Trees from Different Seed Source Localities
Growing in Three Different Plantations Established in 1915 and Rank
of Each Seed Source Locality Within Each Plantation According to Height
in 1931 and Diameter in 1941

Seed source locality	Plantation								
	Wind River			Siuslaw			Mt. Hood A		
	1931	1941		1931	1941		1931	1941	
	Rank	Diameter	Rank	Rank	Diameter	Rank	Rank	Diameter	Rank
		Inches			Inches			Inches	
Palmer	2	5.8	2	4	6.6	2-3	1	3.2	1-2
Gates	6-7	5.7	3	9	6.3	5	4	3.1	3
Granite Falls	1	6.0	1	3	6.2	6	3	2.7	4-5
Darrington	3-5	5.2	6-7	1	6.5	4	6-7	2.7	4-5
Carson	13	4.9	12	5-6	6.0	7-8	10-11	2.2	10-12
Wind River	10-11	4.8	13	8	5.1	12	10-11	2.2	10-12
Lakeview	8-9	5.1	8-10	5-6	6.0	7-8	8	2.4	9
Portland	8-9	5.1	8-10	10	6.9	1	12	2.1	13
Fortson	3-5	5.3	5	11	5.7	9	6-7	2.6	6-7
Benton	6-7	5.5	4	2	6.6	2-3	13	2.2	10-12
Hazel	3-5	5.0	11	12-13	5.2	11	5	2.6	6-7
Race Track	12	5.2	6-7	7	5.5	10	9	2.5	8
Santiam	10-11	5.1	8-10	12-13	4.8	13	2	3.2	1-2
Average (Weighted)		5.3			5.9			2.7	

1/ The rank of each seed source locality is in numerical order according to the average size of the progeny therefrom, number 1 being the largest, regardless of the significance of small differences. Localities having progeny of the same average size are given the same rank numbers. If, for example, three localities have the same average each might bear the rank 1-3.

Progeny from both open-grown and crowded parents were derived from two localities. Those from the crowded parents of one locality were slightly larger than those from the open-grown parents and those from the open-grown parents of the other locality were slightly larger than those from the crowded parents. The differences were not significant in either case and the numbers of progeny were too small for reliable comparisons.

In only one locality was seed collected from trees growing on a good soil and from trees growing on a rocky soil. The diameters of the progeny from the rocky soil were slightly greater on all plantations except one, but the difference was not highly significant.

Seed from parent trees infected with the heartwood red ring rot (*Fomes pini*) and from uninfected parents of similar age was collected in only two localities. The average diameter of progeny from the uninfected parents of one locality was slightly larger than that from infected parents but the relationship was reversed for the progeny from the other locality. The differences were not significant in either case and the number of progeny from one locality was too small for satisfactory comparisons.

In six localities seed was collected from both trees under 100 years of age and over 100 years. On two of the plantations progeny from the younger Carson parents were significantly larger than those from the older parents, but on the other two plantations the difference in one case was not significant and in the other was reversed. None of the other locality sources showed either a consistent or significant difference between progeny from old and young parent trees.

Needle Cast Disease on Siuslaw Plantation

In the spring of 1938 a needle blight was noticed on a very large proportion of the trees on the Siuslaw plantation. This has been tentatively identified as *Rhabdocline pseudotsugae*. T. W. Childs of the office of Forest Pathology made a detailed examination of nearly 500 progeny to determine if they differed in susceptibility according to the parent tree or seed source. Progeny from eight seed source localities each represented by from two to five, and in one case 15, parent trees were rated on an arbitrary scale according to the amount of needle cast observed. It is not possible precisely to evaluate the results because different observers rated the progeny from different parent trees and the effect of difference between observers cannot be removed with the available data. Dismissing the possible discrepancy between observers the results would indicate that the progeny from certain localities may be more susceptible to the disease although the differences are not great. The results would indicate also that there is a significant difference in susceptibility of the progeny of certain parent trees within the same locality of seed source.

Comparisons of Plantations Regardless of Heredity

"Aside from the findings as to comparative growth of stocks differing in provenance, this experiment affords a basis for studying the comparative annual height growth of plantations, identical as to origin of stock, on lands differing in site quality."^{4/}

A comparison was made of the growth up to 1931 on the several areas, which range from site II to site V. The difference in average height then was very marked, the plantation having the largest trees being the Siuslaw (average height 21.4 feet) and that with the smallest (6.1 feet) being the Mt. Hood B area.

Likewise the diameters in 1941 showed a decided difference, illustrating the effect that climate and soil have on tree growth where other conditions are identical.

Table 3 shows the average diameter of the eight existing plantations in the fall of 1941. It should be noted that the average diameter on the best area, Siuslaw, is three times that of the poorest, Mt. Hood B, plantation of like age.

This demonstrates, as do growth and yield tables, the inherent differences in productivity of different sites, and the greater profitableness for timber production purposes of planting on the good sites.

Recommendations for the Future Course of the Study

The design of the experiment and the results from the 1931 and 1941 measurements do not warrant measurement of the trees for comparison of the different seed lots every five years. At the end of a 10-year period remeasurement and further comparison of the lots should be considered. For this purpose it is not necessary to measure the 1916 plantings since the data do not lend themselves to inclusion with the 1915 plantings and are too few for comparison within the 1915 series.

There is no long-period record of the survival, growth, injury, and mortality of Douglas-fir plantations in this region. Such a record for several sample areas would be desirable as a basis for estimating some of the probabilities for future plantations. The plantations described here could be used as several case studies for that purpose. Since the records of plantation development have already been kept for 26 years a great part of the necessary work has been done. It is, therefore, recommended that the four plantations of the 1915 series and the Snoqualmie 1916 plantation be inspected every five years. At such times the trees should be inspected for injury and mortality and the nails holding the tags should be withdrawn sufficiently to allow for diameter growth. Diameters and heights should be measured on a sample of each plantation to provide a record of plantation

^{4/} See footnote 2.

TABLE 3

Comparison of Average Diameters on the Several
Plantations, Regardless of Heredity

Location of plantation and year planted		Altitude Feet	Site quality	No. of living trees in 1941	Average diameters at breast height in 1941 Inches
Wind River	1915	1,100	III	2,019	5.29
Mt. Hood A	1915	2,800	IV	2,789	2.75
Mt. Hood B	1915	4,600	V	1,322	1.94
Siuslaw	1915	2,100	II	2,109	5.90
Wind River	1916	1,100	III	693	5.09
Mt. Hood A	1916	2,800	IV	838	2.81
Mt. Hood B	1916	4,600	V	341	1.38
Snoqualmie	1916	2,000	II	706	4.72
Totals & Averages (Weighted)					
1915 Plantation				6,917	4.45
1916 Plantation				2,237	4.12

growth. Diameter measurements should include 195 dominant trees with five trees drawn from each of three rows representing each of the 13 seed source localities. The three rows representing a given locality should be selected more or less at random. It is estimated that the composite samples of 195 trees will provide plantation average diameters in which differences of .4 inches will be significant. Height measurements should be made on a sufficient number of these trees to give a satisfactory height and diameter curve. If winter injury on the Mt. Hood B plantation continues at the present rate it may not be desirable to examine it in detail for injuries but merely record general observations for the area as a whole. Further diameter measurements on this plantation will have little value unless the trees recover and at some future time lose the serious effect of their present stem deformities.

Diameter		Height		Remarks	
Tree	Locality	Tree	Locality	Tree	Locality
100	100	100	100	100	100
101	101	101	101	101	101
102	102	102	102	102	102
103	103	103	103	103	103
104	104	104	104	104	104
105	105	105	105	105	105
106	106	106	106	106	106
107	107	107	107	107	107
108	108	108	108	108	108
109	109	109	109	109	109
110	110	110	110	110	110
111	111	111	111	111	111
112	112	112	112	112	112
113	113	113	113	113	113
114	114	114	114	114	114
115	115	115	115	115	115
116	116	116	116	116	116
117	117	117	117	117	117
118	118	118	118	118	118
119	119	119	119	119	119
120	120	120	120	120	120
121	121	121	121	121	121
122	122	122	122	122	122
123	123	123	123	123	123
124	124	124	124	124	124
125	125	125	125	125	125
126	126	126	126	126	126
127	127	127	127	127	127
128	128	128	128	128	128
129	129	129	129	129	129
130	130	130	130	130	130
131	131	131	131	131	131
132	132	132	132	132	132
133	133	133	133	133	133
134	134	134	134	134	134
135	135	135	135	135	135
136	136	136	136	136	136
137	137	137	137	137	137
138	138	138	138	138	138
139	139	139	139	139	139
140	140	140	140	140	140
141	141	141	141	141	141
142	142	142	142	142	142
143	143	143	143	143	143
144	144	144	144	144	144
145	145	145	145	145	145
146	146	146	146	146	146
147	147	147	147	147	147
148	148	148	148	148	148
149	149	149	149	149	149
150	150	150	150	150	150
151	151	151	151	151	151
152	152	152	152	152	152
153	153	153	153	153	153
154	154	154	154	154	154
155	155	155	155	155	155
156	156	156	156	156	156
157	157	157	157	157	157
158	158	158	158	158	158
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162	162	162	162	162	162
163	163	163	163	163	163
164	164	164	164	164	164
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170	170	170	170	170	170
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195	195	195	195	195	195